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Renewable energy in India: Current status and future potentials

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ABSTRACT

Renewable energy sources and technologies have potential to provide solutions to the long-standing energy problems being faced by the developing countries. The renewable energy sources like wind energy, solar energy, geothermal energy, ocean energy, biomass energy and fuel cell technology can be used to overcome energy shortage in India. To meet the energy requirement for such a fast growing economy, India will require an assured supply of 3–4 times more energy than the total energy consumed today. The renewable energy is one of the options to meet this requirement. Today, renewable account for about 33% of India's primary energy consumptions. India is increasingly adopting responsible renewable energy techniques and taking positive steps towards carbon emissions, cleaning the air and ensuring a more sustainable future. In India, from the last two and half decades there has been a vigorous pursuit of activities relating to research, development, demonstration, production and application of a variety of renewable energy technologies for use in different sectors. In this paper, efforts have been made to summarize the availability, current status, major achievements and future potentials of renewable energy options in India. This paper also assesses specific policy interventions for overcoming the barriers and enhancing deployment of renewables for the future.

Contents

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1. Introduction

The World Energy Forum has predicted that fossil-based oil, coal and gas reserves will be exhausted in less than another 10 decades. Fossil fuels account for over 79% of the primary energy consumed in the world, and 57.7% of that amount is used in the transport sector and are diminishing rapidly [1]. The exhaustion of natural resources and the accelerated demand of conventional energy have forced planners and policy makers to look for alternate sources. Renewable energy is energy derived from resources that are regenerative, and do not deplete over time. Renewable energy offers our planet a chance to reduce carbon emissions, clean the air, and put our civilization on a more sustainable footing. It also offers countries around the world the chance to improve their energy security and spur economic development. Modern biomass encompasses a range of products derived from photosynthesis and is essentially chemical solar energy storage. Renewable energy supplies 18% of the world's final energy consumption (Fig. 1), counting traditional biomass, large hydropower, and "new" renewables (small hydro, modern biomass, wind, solar, geothermal, and biofuels). Traditional biomass, primarily for cooking and heating, represents about 13% and is growing slowly in some regions as biomass is used more efficiently or replaced by more modern energy forms. Large hydropower represents 3% and is growing modestly, primarily in developing countries [2]. New renewables represents 2.4% and are growing very rapidly in developed countries and in some developing countries. Global renewable energy capacity grew at rates of 15–30% annually for many technologies during the five-year period 2002–2006, including wind power, solar hot water, geothermal heating, and off-grid solar PV (Fig. 2) [3]. Renewable energy markets grew robustly in 2008. Among new renewables (excluding large hydropower), wind power was the largest addition to renewable energy capacity. An estimated $120 billion was invested in renewable energy worldwide in 2008, including new capacity (asset finance and projects) and biofuels refineries Fig. 3 [4].

Renewable energy sources (RES) that use indigenous resources have the potential to provide energy with negligible emissions of air pollutants and green house gases [5]. Renewable energy technologies produce marketable energy by converting natural phenomena/resources into useful energies. The usage of renewable energy resources is a promising prospect for the future as an alternative to conventional energy. Therefore, an attempt has been made through this paper to review the availability of renewable energy options in India, and provides information about the current status of renewable, future potentials of their uses, major achievements, and current government policies, delivery and outreach in Indian context. It paints a remarkable overall picture of renewable energy resources and position of India on global map in utilizing these resources.

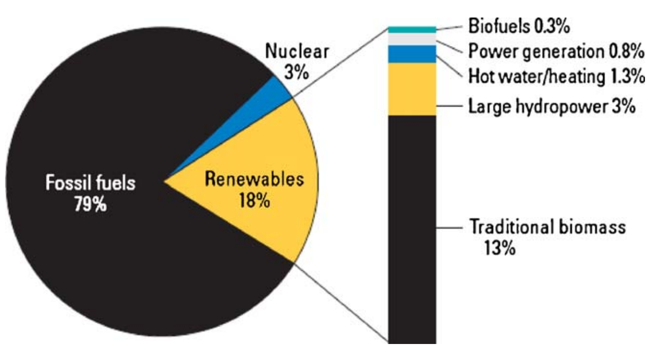


Fig. 1. Renewable energy share of global final energy consumption.

2. Renewable energy in India

India's population of more than 1028 million is growing at an annual rate of 1.58%. As fossil fuel energy becomes scarcer, India will face energy shortages significantly due to increase in energy prices and energy insecurity with in the next few decades. Increased use of fossil fuels also causes environmental problems both locally and globally. The economy of India, measured in USD exchange-rate terms, is the twelfth largest in the world, with a GDP of around $1 trillion (2008). GDP growth rate of 9.0% for the fiscal year 2007–2008 which makes it the second fastest big emerging economy, after China, in the world. There is a very high demand for

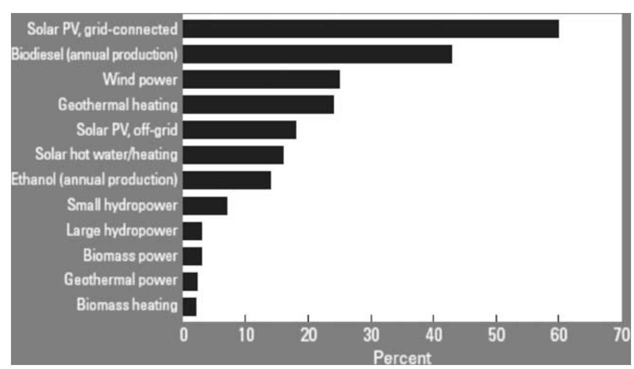


Fig. 2. Average annual growth rates of renewable energy capacity, 2002–2006.

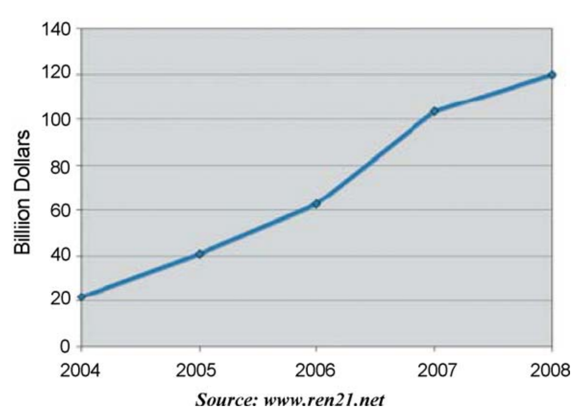


Fig. 3. Global investment in renewable energy, 2004–2008.

Table 1
Energy demand projection in India.

Sl. No.	Source	Unit	1991–1992	2009–2010	2020–2021
1	Electricity	TWh	231	725	1300
2	Coal	Mt.	229	690	1345
3	Petroleum products	Mt.	57	165	335
4	Natural gas	b cum	18.6	65	130

energy, which is currently satisfied mainly by coal, foreign oil and petroleum, which apart from being a non-renewable, and therefore non-permanent solution to the energy crisis, it is also detrimental to the environment. Thus, it is imperative that India obtains energy security without affecting the booming economy, which would mean that the country must switch from the nonrenewable energy (crude oil and coal) to renewable energy.

For these reasons the development and use of RES & Technologies are becoming vital for sustainable economic development of India. Expert consultation at the Asia Energy Vision 2020, organized under the World Energy Council agreed on energy demand projection in India up to 2020 as given in Table 1 [6]. The Expert Committee on Integrated Energy Policy in its Report (IEPR 2006) has estimated that by 2032, i.e., 25 years from now primary commercial energy requirement in the country would need to go up 4–5 times the current level, electricity generation installed capacity 5.6–7 times the current level and oil requirement by 3–6 times the current level.

Energy is a basic requirement for economic development and in every sector of Indian economy. It is thus necessary that India quickly look towards new and emerging renewable energy and energy efficient technologies as well as implement energy conservation laws. Against this background, the country urgently needs to develop a sustainable path of energy development. Promotion of energy conservation and increased use of renewable energy sources are the twin planks of a sustainable energy supply. Fortunately, India is blessed with a variety of renewable energy sources, like biomass, the solar, wind, geothermal and small hydropower and implementing one of the world's largest programs in renewable energy.

India is determined to becoming one of the world's leading clean energy producers. The Government of India has already made several provisions, and established many agencies that will help it to achieve its goal. Renewable energy, excluding large hydro projects already account for 9% of the total installed energy capacity, equivalent to 12,610 MW of energy. In combination with large hydro, the capacity is more than 34%, i.e., 48,643 MW, in a total installed capacity of 144,980 MW. Fig. 4 is showing installed power capacity (MW) in India.

The country has an estimated renewable energy potential of around 85,000 MW from commercially exploitable sources, i.e., wind, 45,000 MW; small hydro, 15,000 MW and biomass/bioenergy, 25,000 MW. In addition, India has the potential to generate 35 MW per square kilometer using solar photovoltaic and solar thermal energy. By March 2007, renewable electricity, excluding hydro above 25 MW installed capacity, has contributed 10,243 MW representing 7.7% of total electricity installed capacity. There has been phenomenal progress in wind power and, with an installed capacity of over 8757 MW, India occupies the fifth position globally [4–7].

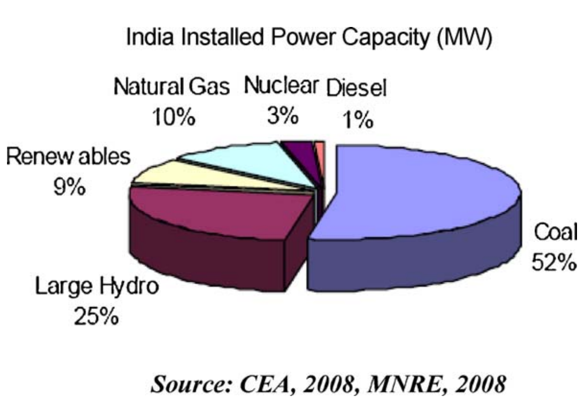


Fig. 4. Installed power capacity (MW) in India as of June 2008.

The role of new and renewable energy has been assuming increasing significance in recent times with the growing concern for the country's energy security. The renewable energy industry has approximately USD 500 million as turnover, the investment being about USD 3 billion. Of the estimated potential of 100,000 MW from RE only about 3500 MW has been exploited to-date. The Indian Government has been at work, making a comprehensive policy for compulsory use of renewable energy resources through biomass, hydropower, wind, solar and municipal waste in the country, particularly for commercial establishments, as well as Government establishments.

The major contribution to renewable energy investment comes from private sector participation. This is due to the support from the government, which leverages the private investment. The financial allocation for renewable energy sources vis-à-vis total allocation, however, remains in the range of 0.1% during Tenth Plan period. This is expected to increase during the Eleventh Plan (Table 2) [8].

According to the 11th new and renewable energy five-year plan proposed by the government of India, from 2008 to 2012 the renewable energy market in India will reach an estimated US $19 billion. Investments of US $15 billion will be required in order to add the approximately 15,000 megawatts (MW) of renewable energy to the present installed capacity. The Indian government has also set specific targets for renewable energy by 2012 it expects renewable energy to contribute 10% of total power generation capacity and have a 4–5% share in the electricity mix. This implies that growth in renewable energy will occur at a much faster pace than traditional power generation, with renewables making up 20% of the 70,000 MW of total additional energy planned from 2008 to 2012. From 2002 to 2007, there was 3075 MW of renewable grid-tied power planned, but the actual capacity addition exceeded 6000 MW by 2006. A large share of this was the result of exceptional growth of wind energy in India. Wind energy is expected to add more than 10,000 MW of additional capacity by 2012, followed by small hydro (1400 MW), co-generation (1200 MW) and biomass (500 MW). Ministry of Non-conventional Energy Sources is focused on nation-wide resource assessment, setting up of commercial projects, renovation and modernization, development and up-gradation of water mills and industry based research and development.

The Ministry of New and Renewable Energy has identified renewable energy R&D as an important factor for developing this

Table 2
Allocation to renewable energy vis-a vis conventional energy sources [6].

Five-year plan (period)	Energy sector outlay (percentage of total plan outlay)	Percentage share in the total plan allocation			
		Power	Oil/gas	Coal	Renewables
Sixth (1980–1985)	28.1	16.7	7.8	3.5	0.1
Seventh (1985–1990)	28.2	17.4	7.3	3.2	0.3
Eight (1992–1997)	26.5	18.4	5.5	2.4	0.3
Ninth (1997–2002)	25.58	14.5	8.6	2.04	0.44
Tenth (2002–2007)	27.26	18.2	6.46	2.12	0.48

Table 3
Renewable energy in India at a glance [7].

Sl. no.	Source/system	Estimated potential	Achievements (as on 30 September 2008)
I	A power from renewables		
A.	Grid interactive renewable power	(MW)	(MW)
1.	Wind power	45,195	9521.80
2.	Biopower (agroresidues and plantations)	16,881	656.60
3.	Bagasse cogeneration	5000	993.83
4.	Small hydro (up to 25 MW)	15,000	2220.99
5.	Energy recovery from waste (MW)	2700	55.25
6.	Solar photovoltaic power	–	2.12 MW
	Sub total (A)	**84.776**	**13,450.59**
B.	Captive/combined heat and power/distributed renewable power		
7.	Biomass/cogeneration (non-baggase)	–	136.70
8.	Biomass gasifiers	–	102.21
9.	Energy recovery from waste	–	31.07
	Sub total (B)	–	**269.98**
	Total (A+B)	**84.776**	**13,720.57**
II	Remote village electrification		**5379 villages/hamlets**
III	Decentralized energy systems		
10.	Family-type biogas plants	120 lakh	40.32 lakh
11.	Solar photovoltaic systems	50 MW/km^2	120 MWp
	i. Solar street lighting systems	–	70,474 nos.
	ii. Home lighting systems	–	434,692 nos.
	iii. Solar lanterns	–	697,419 nos.
	iv. Solar power plant	–	8.01 MWp
	v. Solar photovoltaic pumps	–	7148 nos.
12.	Solar thermal systems		4,78,058 nos.
	i. Solar water heating systems	140 million m^2 of collector area	2.45 million m^2 of collector area
	ii. Solar cookers	–	6.37 lakhs
13.	Wind pumps	–	1342 nos.
14.	Aero generators/hybrid systems		723.00 kW
IV	Awareness programs		
15.	Energy parks	–	516 nos.
16.	Aditya Solar Shops	–	269 nos.
17.	Renewable Energy Clubs	–	521 nos.
18.	Distric Advisory Committees	–	560 nos.

MW = mega-watt; m^2 = square meter; km^2 = kilowatt; MWp = mega watt peak

MNRE (www.mnre.gov.in).

sector. R&D subsidy is 100% of a project's cost in government R&D institutions, and 50% in the private sector. The R&D subsidy for the private sector may be enhanced for initial stages of technologies that have longer time-horizons. Renewable sources already contribute to about 5% of the total power generating capacity in the country. During the last two decades, several renewable energy technologies have been deployed in rural and urban areas. Some of the achievements are given in Table 3 along with the estimated potential [9].

2.1. Biomass

In recent years, the interest in using biomass as an energy source has increased and it represents approximately 14% of world final energy consumption [10]. Estimates have indicated that 15–50% of the world's primary energy use could come from biomass by the year 2050. Many countries have included the increased use of renewable sources on their political agenda. Biomass is one such resource that could play a substantial role in a more diverse and sustainable energy mix. The energy obtained from biomass is a form of renewable energy and, in principle, utilizing this energy does not add carbon dioxide, a major greenhouse gas, to the atmosphere, in contrast to fossil fuels. As per an estimate, globally photosynthesis produces 220 billion dry tonnes of biomass each year with 1% conversion efficiency [11–13]. Biomass resources suitable for energy production covers a wide range of materials, from firewood collected in farmlands and natural woods to agricultural and forestry crops grown specifically for energy production purposes. Energy production from food wastes or food processing wastes, especially from waste edible oils, seems to be attractive based on bio-resource sustainability, environmental protection and economic consideration. India is very rich in biomass and has a potential of 16,881 MW (agro-residues and plantations), 5000 MW (bagasse cogeneration) and 2700 MW (energy recovery from waste) [7]. Biomass power generation in India is an industry that attracts investments of over Rs. 600 crores every year, generating more than 5000 million units of electricity and yearly employment of more than 10 million man-days in the rural areas.

2.2. Hydropower

Hydropower is another source of renewable energy that converts the potential energy or kinetic energy of water into mechanical energy in the form of watermills, textile machines, etc., or as electrical energy (i.e., hydroelectricity generation). It refers to the energy produced from water (rainfall flowing into rivers, etc.). Hydropower is the largest renewable energy resource being used for the generation of electricity. Only about 17% of the vast hydel potential of 150,000 MW has been tapped so far. Countries like Norway, Canada, and Brazil have all been utilizing more than 30% of their hydropotential, while on the other hand India and China have lagged far behind. India ranks fifth in terms of exploitable hydropotential in the world. According to CEA (Central Electricity Authority), India is endowed with economically exploitable hydropower potential to the tune of 148,700 MW. The basin-wise assessed potential is shown in Table 4 [14].

Table 4
Basin wise assessed hydropower potential [11].

Basin/Rivers	Probable installed capacity (MW)
Indus basin	33,832
Ganga basin	20,711
Central Indian river system	4152
Western flowing rivers of southern India	9430
Eastern flowing rivers of southern India	14,511
Brahmaputra basin	66,065
Total	148,701

Narmada Hydroelectric Development Corporation website.

The dominant annual rainfall is located on the North-Eastern part of India: Arunachal Pradesh, Assam, Nagaland, Manipur and Mizoram, and also on the west coast between Mumbai (Bombay) and Mahe. Primary hydroelectric power plants are located in Bihar, Punjab, Uttaranchal, Karnataka, Uttar Pradesh, Sikkim, Jammu & Kashmir, Gujarat, and Andhra Pradesh. In India, hydropower projects with a station capacity of up to 25 megawatt (MW) fall under the category of small hydropower (SHP). India has an estimated SHP potential of about 15,000 MW, of which about 11% has been tapped so far. The Ministry of New and Renewable Energy (MNRE) supports SHP project development throughout the country. So far, 523 SHP projects with an aggregate installed capacity of 1705 MW have been installed. Besides these, 205 SHP projects with an aggregate capacity of 479 MW are under implementation. With a capacity addition, on an average, of 100 MW per year and gradual decrease in gestation periods and capital costs, the SHP sector is becoming increasingly competitive with other alternatives.

Some key figures concerning small hydro in India:

• Less than 25 MW is in the “small hydro” designation • There is a potential of 15,000 MW	• 4096 potential sites have been identified • Technology is mature and reliable
• Installed is 1520 MW to date	• Two types of technology are used (i) High-head systems (ii) Low-head systems

2.3. Wind energy

Winds are generated by complex mechanisms involving the rotation of the earth, heat energy from the sun, the cooling effects of the oceans and polar ice caps, temperature gradients between land and sea and the physical effects of mountains and other obstacles. Wind is a widely distributed energy resource. Total world wind capacity at the end of 2006 was around 72,000 MW. Wind energy is being developed in the industrialized world for environmental reasons and it has attractions in the developing world as it can be installed quickly in areas where electricity is urgently needed. In many instances it may be a cost-effective solution if fossil fuel sources are not readily available. In addition there are many applications for wind energy in remote regions, worldwide, either for supplementing diesel power (which tends to be expensive) or for supplying farms, homes and other installations on an individual basis.

The availability of wind varies for different regions. Wind resources can be exploited mainly in areas where wind power density is at least 400 W/m^2 at 30 m above the ground. The Wind Resource Assessment Program is being implemented by C-WET (Centre for Wind Energy Technology) in coordination with state nodal agencies. An annual mean wind power density greater than 200 W/m^2 (watts per square meter) at 50-m height has been recorded at 211 wind monitoring stations, covering 13 states and

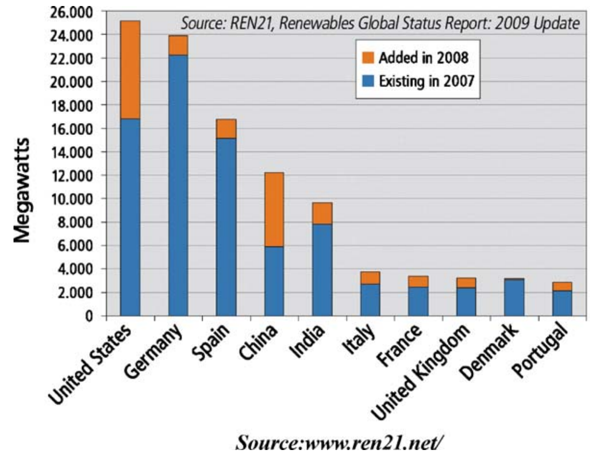


Fig. 5. Wind power capacity, top ten countries, 2008.

union territories, namely Andaman and Nicobar Islands, Andhra Pradesh, Gujarat, Karnataka, Kerala, Lakshadweep, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, Tamil Nadu, Uttaranchal, and West Bengal. India’s wind power potential has been assessed at 45,000 MW. A capacity of 8757 MW up to 31 March 2008 has so far been added through wind (Fig. 5) [4]. The Wind Power Program in India was initiated towards the end of the Sixth Plan, in 1983–1984. The program aims at survey and assessment of wind resources, setting up demonstration projects, and provision of incentives to make wind electricity competitive.

India is surpassed only by Germany as one of the world’s fastest growing markets for wind energy. By the mid 1990s, the subcontinent was installing more wind generating capacity than North America, Denmark, Britain, and the Netherlands. The ten machines near Okha in the province of Gujarat were some of the first wind turbines installed in India. These 15-m Vestas wind turbines overlook the Arabian Sea. Now, in 2008, there is an installed capacity of 5310 MW; however, ten times that potential, or 45,000 MW, exists. Different types of Wind Power Generators used in India for Off grip Power generation, i.e., water-pumping windmills, aero-generators (a small wind electric generator having a capacity of up to 30 kW) and wind–solar hybrid systems [15].

2.4. Solar energy

Solar energy is the most abundant permanent energy resource on earth and it is available for use in its direct (solar radiation) and indirect (wind, biomass, hydro, ocean, etc.) forms. Solar energy, experienced by us as heat and light, can be used through two routes: the thermal route uses the heat for water heating, cooking, drying, water purification, power generation, and other applications; the photovoltaic route converts the light in solar energy into electricity, which can then be used for a number of purposes such as lighting, pumping, communications, and power supply in un electrified areas.

The total annual solar radiation falling on the earth is more than 7500 times the world’s total annual primary energy consumption of 450 EJ. The annual solar radiation reaching the earth’s surface, approximately 3,400,000 EJ, is an order of magnitude greater than all the estimated (discovered and undiscovered) non-renewable energy resources, including fossil fuels and nuclear. However, 80% of the present worldwide energy use is based on fossil fuels. Most parts of India receive 4–7 kWh of solar radiation per square meter per day with 250–300 sunny days in a year. The highest annual radiation energy is received in Western Rajasthan while the North-Eastern region of the country receives the lowest annual radiation. India has a good level of solar radiation, receiving the solar energy

equivalent of more than 5000 trillion kWh/yr. Depending on the location, the daily incidence ranges from 4 to 7 kWh/m^2, with the hours of sunshine ranging from 2300 to 3200 per year.

The MNRE, working in conjunction with the Indian Renewable Energy Development Agency (IREDA) to promote the utilization of all forms of solar power as well as to increase the share of renewable energy in the Indian market. This promotion is being achieved through R&D, demonstration projects, government subsidy programs, and also private sector projects.

The Prime Minister released the National Action Plan on Climate Change (NAPCC) on 30th June, 2008. The Plan proposes to start 8 missions, amongst which one is the National Solar Mission [15]. Solar thermal and solar photovoltaic technologies are both encompassed by the Solar Energy Program that is being implemented by the Ministry (regarded as one of the largest in the world) to utilize India's estimated solar power potential of 20 and 35 MW/km^2 solar thermal. India's overall potential for solar water heating systems has been estimated to be 140 million m^2 of collector area. A Government scheme for 'Accelerated development and deployment of Solar Water Heating systems in domestic, industrial and commercial sectors' has been introduced, with the object of promoting the installation of another million m2 of collector area during FY 2005–2006 and 2006–2007. The scheme offers a number of financial and promotional incentives, along with other measures of support. Solar air heating technology has been applied to various industrial and agricultural processes (e.g. drying/curing, regeneration of dehumidifying agents, timber seasoning, leather tanning) and also for space heating; many types of solar dryers have been developed for use in different situations. The Government provides financial support for solar air heating/drying systems, and also for solar concentrating systems. Solar buildings have been promoted by the MNRE in an effort to increase energy efficiency; the state government in Himachal Pradesh has actively promoted the incorporation of passive solar design into building design. The Solar Photovoltaic Program (SPV) promoted by the Ministry for the past two decades, has been aimed particularly at rural and remote areas. Following the success of the country-wide SPV demonstration and utilization program during the period of the Ninth Plan, it is planned, with certain modifications, to continue it during the Tenth Plan (2002–2007). The Ministry has the objective that by 2010 they will all have access to power from renewable energy sources [8].

2.5. Geothermal energy

Geothermal is energy generated from heat stored in the earth, or the collection of absorbed heat derived from underground. Immense amounts of thermal energy are generated and stored in the Earth's core, mantle and crust. Geothermal energy is at present contributing about 10,000 MW over the world and India's small resources can augment the above percentage. Studies carried out by the geological survey of India have observed existence of about 340 hot springs in the hot country. These are distributed in seven geothermal provinces. The provinces, although found along the west coast in Gujarat and Rajasthan and along a west south west-east-northeast line running from the west coast to the western border of Bangladesh (known as SONATA), are most prolific in a 1500 km stretch of the Himalayas. The resource is little used at the moment but the Government has an ambitious plan to more than double the current total installed generating capacity by 2012.

3. Other renewable energy technologies

Solar thermal technologies, particularly solar water heating system, solar cookers and solar generation systems are the most commercialized technologies among renewable energy technologies in India. Policies are set to provide further impetus to dissemination of solar technologies.

Biogas represents an alternative source of energy, derived mainly from organic wastes. In India, the use of biogas derived from animal waste, primarily cow dung, has been promoted for over three decades now. Biogas is a clean fuel produced through anaerobic digestion of a variety of organic wastes: animal, agricultural, domestic, and industrial. Biogas is the only technology that has put cooking in rural areas on technological ladder and has made cooking a pleasure with associated social and environmental benefits including zero indoor pollution. India's National Project on Biogas development (NPBD) has been one of the well organized and systematic program to provide logistic and institutional support for that has been under implementation since early 1980s. India Biogas program is one of the most successful program if we compare with other such program implemented in Rural India. Till December 2004, under the National Biogas Program, over 3.7 million biogas plants in the capacity of 1–6 m^3 had been installed. The ultimate goal of this program is to set up biogas plants in around 12 million households that have enough cattle to maintain a regular supply of dung.

Biofuel program in the country is at nascent stage. The policy measures currently in place include an excise tax reduction for E-5, the obligation to blend all petrol with 5% ethanol in certain regions since January 2003 and government regulation of the ethanol selling price on the basis of ethanol production costs. Subsequently the percentage of ethanol mixture in petrol is planned to be increase to 10%. A new biofuel policy for the country is under construction.

Hydrogen energy is also at early stage of development. Ministry of New and Renewable Energy also funded research projects on different aspects of hydrogen energy technology development. India is the member of the International Partnership on Hydrogen economy (IPHE) set up in Washington, DC in November 2003. Future challenges to India includes lowering cost of hydrogen substantially and improve production rates from different methods, development of compact and inexpensive storage capacity, establishment of hydrogen network and development of hydrogen fuelled IC engine and efficiency improvement of different type of fuel cell systems. The road map envisages taking up of research, development and demonstration activities in various sectors of hydrogen energy technologies and visualized goals of one million hydrogen-fuelled vehicles and 1000 MW aggregate hydrogen based power generation capacity to be set up in the country by 2020 [16].

4. Environmental sustainability: renewable energy and climate change

To sustain economic growth and raise living standards, energy shortages could be met by increasing supplies. But there are two other important considerations: environmental sustainability and social development. The current pattern of economic growth has caused serious environmental damage – polluting the air, creating large quantities of waste, degrading biological systems and accelerating climate change – with many of these effects coming from the energy sector. At the same time, it is also vital to consider the impact on social development. The lack of access to energy services aggravates many social concerns, including poverty, ill-health, unemployment and inequity.

In modern economic sectors one of the main sources of energy is oil. Although the world's largest oil consumer is still the United States, four Asian countries are not far behind; China comes second, Japan third, India fourth and the Republic of Korea sixth [17]. Natural gas is also increasingly important: its fuel efficiency

makes it an attractive choice for new power generating plants and for the industrial sector.

Other environmental concerns include water pollution and the disposal of waste, particularly nuclear waste. In the rural areas one worry is the overexploitation of environmentally sensitive areas. Many people in rural areas rely on biomass fuels for cooking, heating and lighting. Overuse of these can lead to degradation of watersheds, and loss of biodiversity and habitats. About 70% of total greenhouse gas (GHG) emissions are related to energy, mainly from the combustion of fossil fuels for heat, electricity generation and transport. Countries have many options for reducing GHG emissions-at minimal, zero or even net negative costs. These include energy conservation along with increases in efficiency, better energy management, cleaner production and consumption, and changes in lifestyles. Renewable and other more efficient technologies would also help mitigate climate change. Overall, countries can foster science-based decision-making that creates incentives for cleaner and more energy-efficient economic activities while increasing people's access to modern energy services.

4.1. Climatic changes

Climatic changes, as a result of global warming caused by greenhouse gases, mainly carbon dioxide (CO_2) produced during the burning of fossil fuels, have been causing significant changes in the ecosystems and leading to nearly 150,000 additional deaths every year [2]. This rise is mainly caused by the unsustainable use of fossil fuels and the changes in the use of the land [18].

4.2. Clean development mechanism

The clean development mechanism (CDM) of the Kyoto Protocol has been set up to assist developing countries in achieving sustainable development by promoting greenhouse gas emission reduction projects, that generate emission credits (certified emissions reductions, CERs) for industrialized countries [19]. A number of countries in the region are taking advantage of the CDM. This is a provision of the Kyoto Protocol which was devised originally as a bilateral mechanism through which entities in industrialized countries could gain certified emission reductions (CERs) by investing in clean technologies in developing countries. For the recipient developing countries, this can boost returns on projects by up to 12% for wind, hydro and geothermal projects and by 15–17% for biomass and municipal waste projects (UNEP). Indian enterprises have already committed investment to generate more than 379 million CERs. Worldwide investments have been made that will generate 1.9 billion CERs by 2012.

5. Future of renewable energy in India

India, faced with twin challenges on energy and environmental front, has no option but to work towards increasing the role of renewable in the future energy systems. Renewable energy technologies vary widely in their technological maturity and commercial status. In India, renewable energy is at the take-off stage and businesses, industry, government and customers have a large number of issues to address before these technologies could make a real penetration. India with large renewable energy resources (solar PV, wind, solar heating, small hydro and biomass) is to set to have large-scale development and deployment of renewable energy projects [20]. The aim of meeting 10% of the country power supply through renewable by 2012 and also ambitious plans for the distribution of biogas plants, solar PV applications and solar city appears to be within reach. Moreover, introduction of tradable renewable energy certificates (REC) could overcome the existing gap that is hindering the application of quota for renewables and thereby creates a vibrant market.

India would also have to look for international cooperation in renewable energy through well defined R&D projects with proper division of labour and responsibilities for specific tasks with equitable financial burden and credit sharing arrangements. Renewable energy development is considered in India to be of great importance from the point of view of long term energy supply security, environmental benefits and climate change mitigation. The Integrated Energy Policy report has recognized the need to maximally develop domestic supply options as well as the need to diversify energy sources. The Committee has placed emphasis on higher use of renewables in all forms of services. It is expected that the contribution from renewables in power generation alone can be of the extent of 60,000 MW in the year 2031–2032. By 2031–2032 renewables will be the key driver in social inclusion of the poor in the development process. A modest assessment of investments in the renewable energy sector will be about Rs. 300,000 crores over the next 25 years. MNRE has included in its mission: energy security; increase in the share of clean power; energy availability and access; energy affordability; and energy equity [21].

A number of government and private organizations such as MNRE, Centre for Wind Energy Technology, Universities, IITs, NITs, Indian Oil Corporation Ltd. (IOCL) and The Energy Resource Institute (TERI) are involved in R&D of renewable energy sources.

6. Current energy policies

The ultimate objective of the renewable energy policy framework is to significantly increase the share of renewable energy source in India's energy mix [20]. These energy policies are set by government.

6.1. National Electricity Policy, 2005

The National Electricity Policy aims at achieving the following objectives; access to electricity, availability of power demand (to be fully met by 2012), energy and peaking shortages to be overcome and spinning reserve to be available, supply of reliable and quality power of specified standards in an efficient manner and at reasonable rates, per capita availability of electricity to be increased to over 1000 units by 2012, financial turn around and commercial viability of electricity sector and protection of consumers' interests.

6.2. The Electricity Act 2003

The Electricity Act contains the following provisions pertaining to non-conventional energy sources.

Under Sections 3(1) and 3(2), it has been stated that the Central Government shall, from time to time, prepare and publish the National Electricity Policy and Tariff Policy, in consultation with the state governments and authority for development of the power system based on optimal utilization of resources such as coal, natural gas, nuclear substances or material, hydro and renewable sources of energy. Section 4 states that the Central Government shall, after consultation with the state governments, prepare and notify a national policy, permitting stand-alone systems for rural areas. Section 61, 61(h) and 61(i) state that the appropriate commission shall, subject to the provision of this Act, specify the terms and conditions for the determination of tariff, and in doing so, shall be guided by the following, namely, the promotion of cogeneration and generation of electricity from renewable sources of energy; and the National Electricity Policy and Tariff Policy. Section 86(1) and 86(1)(e) state that the state commissions shall discharge the following functions, namely, promote cogeneration

and generation of electricity from renewable sources of energy by providing, suitable measures for connectivity with the grid and sale of electricity to any person, and also specify, for purchase of electricity from such sources, a percentage of the total consumption of electricity in the area of a distribution license.

6.3. Tariff Policy, 2006

The Tariff Policy announced in January 2006 has the following provisions:

1. Pursuant to provisions of section 86 (1) (e) of the Act, the Appropriate Commission shall fix a minimum percentage for purchase of energy from such sources taking into account availability of such resources in the region and its impact on retail tariffs.
2. It will take some time before non-conventional technologies can compete with conventional sources in terms of cost of electricity. Therefore, procurement by distribution companies shall be done at preferential tariffs determined by the Appropriate Commission.
3. Such procurement by Distribution Licensees for future requirements shall be done, as far as possible, through competitive bidding process under Section 63 of the Act within suppliers offering energy from same type of non-conventional sources.
4. The Central Commission should lay down guidelines within three months for pricing non-firm power, especially from non-conventional sources, to be followed in cases where such procurement is not through competitive bidding.

6.4. National Rural Electrification Policies, 2006

1. Goals include provision of access to electricity to all households by the year 2009, quality and reliable power supply at reasonable rates, and minimum lifeline consumption of 1 unit/household/day as a merit good by year 2012.
2. For villages/habitations where grid connectivity would not be feasible or not cost effective, off-grid solutions based on stand-alone systems may be taken up for supply of electricity.
3. State government should, within 6 months, prepare and notify a rural electrification plan, which should map and detail the electrification delivery mechanism.
4. The Gram Panchayat shall certify and confirm the electrified status of the village as on 31st March each year.

6.5. Integrated Energy Policy Report (Planning Commission) 2006

Suggest a path to meet energy needs of the country in an integrated manner up to 2031–2032. It recommended special focus on renewable energy development.

7. Initiatives and steps for delivery and outreach

7.1. District Advisory Committees (DACs)

These Committees have led to the creation of an effective renewable energy promotion network at the grass-root level that will also help in integration of renewable energy schemes with those of other development departments. To date, 550 DACs have been setup in 550 districts of the country.

7.2. Akshay Urja Shops (renewable energy shops)

Akshay Urja Shops were launched to cover all districts of the country to ensure easy availability of such systems/devices. It is expected that the common man will embrace renewable energy technologies in a big way for augmenting energy needs of cooking, lighting and motive power from these shops.

7.3. Energy parks

With a view to integrating the activities of State and District Levels Energy Parks was set up at the national level.

7.4. Rajiv Gandhi Akshay Urja Diwas (Rajiv Gandhi Renewable Energy Day)

The birth anniversary of former Prime Minister, late Sh. Rajiv Gandhi on 20th August 2006 was observed as 'Rajiv Gandhi Akshay Urja Diwas' all over the country is organize to increase awareness on a mass-scale at National, State and District levels.

7.5. Akshay Urja Newsletter (Renewable Energy Newsletter)

A bi-monthly newsletter titled 'Akshay Urja' was started with a focus on national/international renewable energy developments, technological developments, manufacturer's details, renewable energy education, etc.

7.6. Renewable Energy Clubs

A scheme has been evolved to promote the study of renewable energy through the setting up of RE Clubs in AICTE recognized/approved Engineering Colleges/Technology Institutions all over the country to educate and sensitize young and future scientists on various aspects of new and renewable energy.

8. Major achievements

India's major achievements on renewable energy development can be summarized as follows:

- Over 4200 MW grid power from wind, small hydro, biomass and solar energy.
- 3600 remote villages/hamlets, including those in Sunderbans, Bastar, Ladakh and the North East electrified through solar energy.
- Largest solar–steam cooking system for 15,000 persons/day set up at Tirupati Tirumala Devasthanam.
- 7 lakh square meter collector area solar water heating systems installed.
- 3.5 million biogas plants installed for cooking and lighting applications.
- 35 million improved wood stoves in rural homes.
- Integrated Rural Energy Program implemented in 860 blocks.
- 30 MW capacity Solar Photovoltaic products exported to various developed and developing countries.
- 280 Energy Parks set-up in educational institutions for demonstration of renewable energy systems and devices.
- Rs.25, 000 million direct subsidy given so far to beneficiaries/users of renewable energy systems and devices, including subsidy for grid connected renewable power projects.
- Rs. 32,000 million loan provided so far by Indian Renewable Energy Development Agency Limited for 1600 renewable energy projects.
- Centre for Wind Energy Technology set up as a scientific and industrial research organization for wind resource assessment, equipment certification and R&D at Chennai in Tamil Nadu.

- Solar Energy Centre set up for development of solar energy systems and devices at Gurgaon in Haryana.

9. Conclusions

Energy security, economic growth and environment protection are the national energy policy drivers of any country of the world. The need to boost the efforts for further development and promotion of renewable energy sources has been felt world over in light of high prices of crude oil. A critical part of the solution will lie in promoting renewable energy technologies as a way to address concerns about energy security, economic growth in the face of rising energy prices, competitiveness, health costs and environmental degradation. According to NAPCC other sources of renewable energy would be promoted. Specific action points that have been mentioned include promoting deployment, innovation and basic research in renewable energy technologies, resolving the barriers to development and commercial deployment of biomass, hydropower, solar and wind technologies, promoting straight (direct) biomass combustion and biomass gasification technologies, promoting the development and manufacture of small wind electric generators, and enhancing the regulatory/tariff regime in order to main stream renewable energy sources in the national power system. Accordingly, increased focus is being laid on the deployment of renewable power that is likely to account for around 5% in the electricity-mix by 2032. Alternate fuels, essentially bio-fuels, are proposed to be progressively used for blending with diesel and petrol, mainly for transport applications. Finally, renewable energy provides enormous benefits and can contribute significantly in the national energy mix at least economic, environmental and social costs and it is expected that the share of renewable energy in the total generation capacity will increase in future.

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